Comparative Analysis on Micro hardness of the ZnO, Al_2O_3 and SiC Particles Reinforced Electro less Ni-P Duplex Coatings

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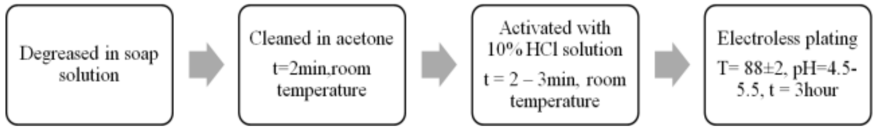
Abstract

Functional performance of components can be increased by the surface coating techniques. Most of the industries need to improve the components performance using several coating techniques. To improve the mild steel surface hardness duplex Ni-P-ZnO/Ni-P-SiC and Ni-P-Al2O3/Ni-P-SiC coatings were tried on it in this investigation. In this study by using dual electroless bath multi- layer coatings is developed. Microhardness of duplex coating measured with assistance of the Vickers microhardness tester. The above mentioned coatings subjected to heat treatment at a temperature of 400oC to enhance the microhardness of the deposit. A comparative study was carried out between both the coatings to know the better alternative to achieve good surface hardness. Results confirm that Ni-P-SiC outer layer duplex coating offers good microhardness. After Heat treatment process, microhardness of the deposit has been increased because of Phase transmission occurs to hard Ni3P from unstructured to structured hard Ni3P. Key words: Duplex coating, nano particles, Microhardness, Heat treatment

Introduction: In 1946, Brenner and Riddell created electro-less Ni plating, which has been used extensively across several sectors since the early 1980s.Many industries rely on composite coatings made of non-electric materials, such as Ni-P and Ni-B. These coatings have many advantages, including superior hardness, surface finish, adhesion, wear resistance, corrosion resistance, and thickness uniformity over complex shapes [1-3].Using a combination of soft and hard particles, composite Ni-P coatings were created. Thickening the second phase with particles of varying sizes (Nano, macro, and micron) improves the tribological and mechanical characteristics of Ni-P plating. The different hard ceramic second phase particles may be deposited to improve features such as hardness, wear resistance, and corrosion resistance [4-6].Microhardness of coatings is influenced by heat treatment, phosphorus content, and particle co-deposition rate. Reinforcing the Ni-P matrix with Nano Al2O3 increases the coating hardness on mild steel by 13%.[7].The creation of hard crystalline Ni and Ni3P structures, as confirmed by a thermal treatment procedure performed at 400oC for Ni-P-Al2O3 coating, accounts for the 135% increase in microhardness. As the hardness of a material increases, the precise wear percentage of a coat decreases [8,9].A coating matrix's partial ability to store the greatest quantity of secondary particles, resulting in a composite coating with reduced microhardness when the SiC particle concentration is maximised. Hence, the ideal concentration of SiC particles was used to create the Ni-P-SiC coating in order to achieve the greatest microhardness value [10,11].Ni-P composite coatings, which include carbon nanotube (CNT) reinforcements in the Ni matrix, have a microhardness 42% higher than Ni-P coatings alone [12].A hardness value of 761 HV was observed for the Ni-P-rGO coat that was generated via the electroless immersion process with 50 mg/L of oxide of grapheme (rGO) [13]. This coating is applied to low carbon steel, which improves the substrate's resistant hardness at the micro level. Adding TiN particles to the Ni lattice makes the Ni-P coating 33% harder at the micro level. The microhardness of Ni-P-TiN coatings is increased by 90% after the heat treatment method [14].When electroless immersion is performed with a zinc oxide component portion at an optimal concentration of 0.5 g/L, the microhardness of a Ni-P-ZnO coating on mild steel is 60% higher than that of the uncoated substrate [15].The self-lubricating qualities and maximal load transfer resistance of CNTs make them superior to SiC particles. Depositing CNTs (Ni-P) into the composite coating results in the highest possible hardness.

To improve the corrosion resistance, wear resistance, and hardness of nickel, composite coatings of Ni-B were created by co-depositing oxides, carbides, and nitride components in the nickel matrix. The corrosion resistance of the Ni-B composite plating is improved by co-deposited SiC [17] and Si3N4 [18], which maintain the anodic dissolution process by decreasing the real metallic zone that is vulnerable to corrosion. Using the Ni-P-Ni-B multi pass plating with double bath, researchers [19-21] studied to acquire ideal characteristics. Compared to Ni-B plating, the multi-pass Ni-B-Ni-P coating has lower microhardness and greater resistance to wear. Improved corrosion resistance compared to Ni-P and Ni-B coatings is a consequence of using Ni-B as an inner layer and Ni-P with a high phosphorus concentration as an outermost layer. The duplex coating's hardness and corrosion resistance are further enhanced by the development of crystalline Ni3P in Ni-P and Ni3B in Ni-B after the heat treatment method [22–24].Comparing the Ni-P inner layered Ni-Co-Al2O3(60g/L) coat to a Ni-Co-Al2O3(60g/L) single layered coat reveals a 20% increase in micro hardness. Duplex Ni-Co-Al2O3 plating with Ni-P as an internal coating provides enhanced corrosion resistance, which is related to Ni-Co-Al2O3 (60g/L) coating [25]. Multipass Ni-P/Ni-P-W coatings are more resistant to microhardness than ternary Ni-P-W and Ni-P coatings. The capacity of the samples to prevent corrosion is arranged in the following sequence, namely, Ni-P < Ni-P-W < Ni-P/Ni-P-W [26].Compared to a Ni-P monolayer coating, a high-boron-medium-phosphorus duplex coat offers better corrosion resistance when exposed to an electrolyte containing sulfuric acid. The corrosion behaviour of multi-pass coatings remains unchanged after heat treatment [27].A small number of studies examined how the concentration of secondary particles in the electroless bath affected the tribological and mechanical characteristics of Ni-P-Ni-B dual coatings. So, in this study, mild steel substrates are coated with Ni-P-Al2O3/Ni-P-SiC and Ni-P-ZnO/Ni-P-SiC at different concentrations of SiC, Al2O3, and ZnO nanoparticles. In this work, the surface hardness of duplex coatings created with varying nanoparticle concentrations is examined in detail.

Methodology: Methodologyadoptedtoexecutethe presentinvestigationchosenfromthepastliteratu



re.Stepsfollowedinthe coatingprocessareschematicallyrepresentationin theFigure 1.

Figure-1: Stepsfollowedintheelectrolesscoating

SelectionofMaterials: Mildsteelwith20x20mm^2 areconsiderasasubstratematerialsforthepresentinvestigation.Electrolessduplexcoatingprocesshasfollowingthreephases(i)Preparationofsubstrate (ii) Preparationchemicalbathand(iii)Coating.

Substrate Preparation: Prior to the pretreatment process substrate was mechanically polished with SiCpapersofgradenumbers100,220,320and420toobtainsmoothsurface.Refinedsubstratewasrinsed with acetone and deionized water to accomplish oil and dirt free face. After that substrate was stimulate inthe10%HClsolutionfor60sectoimprove the adhesion ofthe deposit

Table-1: Electrolessbathcompositionfor duplex

CoatingComposition	Concentration(g/L)
Nickel-chloride	40
Sodium-hypophosphite	20
Trisodium-citrate	25
Ammonia-chloride	50
CTAB	0.8
ZnO,Al_2O_3andSiC nanoparticles	1, 2 and 3
pH	4.5to 5.5
Temperature	88^{o}C(±2)

Chemical Bath Preparation: Chemical components required for the preparation of electroless solution ischosen from past literature. Electroless bath composition and experimental condition required to fabricatemulti layercoatingis shown inTable1

CoatingProcess: TofabricateNi-P-SiCouterlayercoating,initiallychemicallytreatedsubstratematerial is dipped into the ZnO particles mixed solution for 90 minutes to develop Ni-P-ZnO layer. Ni-P-ZnO deposited substrate is immersed into the SiC added solution for 90 minutes to form an external Ni-P-SiC layer. To develop Ni-P-ZnO extreme layer coating initially polished surface submerged into the SiCchemical solution for 90 minutes. Afterwards substrate was immersed into the SiC nanoparticles addedsolution.Anultrasonicagitationtechniquewasusedtodispersethenanoparticlesuniformlyinthechemical solution. Electroless solution distribution of nanoparticles is more uniform in the ultrasonicmethodcomparedtootheragitationtechnique[19and20].Tomaintainconstantcoatingsolutiontemperatureoilbathandhotplate wasused.Solutiontemperaturecontinuously monitorbyusingthermocouple attached PID controller. Entire deposition process constant solution volume 150 ml wasmaintained.PentypepH meterisusedtocheckthepHvalueofsolution.Toknowtheeffectoftemperatureonpropertiesoftheduplexdepositthermaltreatmentcarriedat 400°Ctemperature.Procedure mentioned above is adopted to fabricate multi pass Al_2O_3 and SiC reinforced Ni-Pcoatings.Microhardness of the coating surfaceis examined by using Vickers hardness tester. 100g of load is appliedwithdwelltimeof10sectoexaminethethinfilmmicrohardness.Averageoffivereadingsisconsideredto report the microhardness of the coating.To know the affect of heat treatment temperature all the coatedsubstratematerialsareheated atoptimumtemperature400°Cbyusingmuffle furnace.

ResultsandDiscussions:

Microhardness:

Microhardness of both the duplex Ni-P-ZnO/Ni-P-SiC and Ni-P-Al_2O_3/Ni-P-SiC deposit is analyzed bychangingthenanoparticlesconcentration. Resultsconfirmthatparticleconcentrationinthecoatingsolution significantly affects the coating microhardness. Hardness of both the coated surfaces fabricated atdifferent concentrations of nanoparticles are shown in Figure 2. Increase in particle concentration from1g/L to 2g/L in the bath increases the deposit microhardness value. Higher hardness value is identified inboththedepositsfabricatedatnanoparticles concentration2g/L.Thehighestamountofsecondaryparticles is reinforced into the coating matrix uniformly. Under loading, plastic deformation of alloymatrixispreventedby uniformly reinforcednanoparticles results inbettermicrohardness [28, 29]. Alower microhardness value was observed in the duplex films developed at 3g/L concentration of particles.Particleagglomerationincoatingsolutionathigherconcentrationresultslowerdepositionofparticlesinto the coating matrix. At greater particle concentration, conglomeration of the particles in the coatingsolution negatively affects the multi pass coating hardness. So, minimum microhardness value quoted forboththe coatingfabricatedat3g/Lconcentration of nanoparticles [30-32].

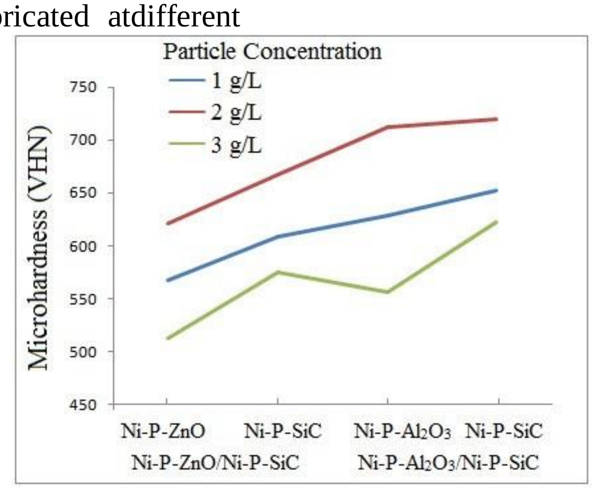


Figure-2: MicrohardnesscomparisonbetweentheNi-P-ZnO/Ni-P-SiCandNi-P-Al_2O_3/Ni-P-SiCcoatings

At all the particle concentrations, the Ni-P-SiC external layer coating's microhardness is superior to theNi-P-ZnOandNi-P-Al_2O_3externallayer.ComparedtoAl_2O_3andZnOnanoparticlesloadcarryingcapacity of the SiC nanoparticles is higher, which restricts the deformation in coating matrix. Therefore,multilayer coating with Ni-P-SiC layer offers better microhardness value. Higher softening nature of theZnOnanoparticlesresultslower microhardnessvaluetotheNi-P-ZnOexternallayer coatings[33].

Duplex coating heat treated at

optimum heat treatment temperature 400 oC significantly improvesits microhardness. After the thermal process microhardness of the coatings developed at different amountsof nanoparticles is represented in Figure 3. After heat treatment process microhardness of both the coatingis significantly improved. Formation of hard crystalline phase from amorphous phase after annealingprocess is the main cause for enhancement in microhardness [34, 35]. Ni-P-Al_2O_3/Ni-P-SiC coatingdeveloped at 2g/L particle concentration shows a maximum hardness value of 985 VHN. Which is 11 %higherthantheNi-P-ZnO/Ni-P-SiCcoatingfabricatedatsamelevel.HardcrystallineNi_3PphaseformationinNi-P-Al_2O_3/Ni-P-SiCcoatingissuperiortotheNi-P-ZnO/Ni-P-SiCcoating.Thereforehardness at micro-level of Ni-P-Al_2O_3/Ni-P-SiC coating is superior to Ni-P-ZnO/Ni-P-SiC coating afterannealingprocess.

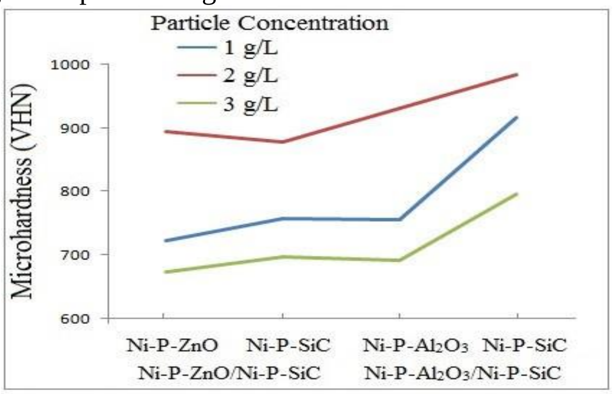


Figure-3: Microhardness of the Ni-P-ZnO/Ni-P-SiC and Ni-P-Al_2O_3/Ni-P-SiC coatings after heattreatment process.

Conclusions:

Dualelectrolessbathisusedtodevelopmultipass Ni-P-SiC/Ni-P-ZnOandNi-P-Al_2O_3/Ni-P-SiCcoatings. Microhardness of the coatings developed at various concentrations of nanoparticles is compared.Basedonthecomparative studyfollowingconclusionsare summarized.

Particleconcentrationinthecoatingsolutionconsiderablyinfluencesthecoatingproperties.Microhardness of all the coatings increases up to 2g/L particles concentration. Particle agglomeration inthecoatingsolution at 3g/Lparticleconcentrationlowers the microhardnessofthecoating.

At the same concentration of nanoparticles microhardness of the Al_2O_3 and SiC reinforced duplex coatingis higher than the ZnO and SiC reinforced duplex coating. Both the coatings higher microhardness valueobserved at 2g/L particle concentration. Maximum microhardness value 720 VHN observed in the Ni-P-SiCexternallayerNi-P-Al_2O_3/Ni-P-SiCduplexcoating.

After heat treatment process further improvement in hardness was identified in all the coatings. FormationofhardcrystallineNi_3Pafterthermalprocesssignificantlyimprovesthemicrohardnessofthecoating.Maximumhardnessvalue985VHNobservedintheNi-P-Al_2O_3/Ni-P-SiCcoatingdevelopedat2g/Lparticle concentration. Which is 11 % higher than the Ni-P-ZnO/Ni-P-SiC coating formed at same level.

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